tensive use on account of their simplicity and the small cost at which they are supplied.

Lieutenant Irvine's floatable trunk is, in the last place, described, which is calculated, not only to preserve apparel, letters, papers, &c, perfectly dry, in case of being thrown overboard, but is also capable of being used as a life-buoy. The largest exhibited before the Society, which is lined with metal, is capable of floating thirty persons. The frame is made of wood, filled in flush with cork, within which is an air casing, extending all over the bottom, top, and sides, and, for ordinary purposes, the interior is lined with Mackintosh cloth. Handles are fixed on the outside for persons immersed in the water to lay hold of.

No. II.

ON ELKINGTON'S PROCESS OF COATING IRON WITH ZINC, COPPER, ETC.

By F. Pellatt.

Nov. 22, 1843.

T. HOBLYN, ESQ., F.R.S., V.P., IN THE CHAIR.

Our present object is to detail the method of protecting iron by coating it with other metals, by means of depositing them from their solutions by an electric current. Iron, from its strength and cheapness, is perhaps the most valuable of all metals, and its application is now universal; it seems as essential to the convenience of man as air or water to his physical wants. The abundant supply of the mineral ore, in connexion with coal, the necessary agent for making it useful, has done much to raise our country to the high standard of political importance it now enjoys among nations.

Valuable, however, as this metal is, it has this drawback, that it is subject to decay under almost every circumstance in which it can be placed, from its strong affinity for oxygen; and, as this agent is present in air, earth, and water, iron is ever liable to be acted upon by this destructive element.

Combining with oxygen, iron becomes what we term rusted, and so insinuating and destructive is this agent, that no sooner is one layer of oxide formed than another begins and undermines it, and so on till the iron is completely corroded.

Seeing how susceptible this metal is of deterioration and decay, it might be thought that much attention had been paid to secure some mode of protecting it, but this has not been the case, probably owing to the extreme cheapness of iron, rendering it necessary that the protecting coating should have, not only the property of indestructibility, but should not add much to the cost of the iron, otherwise it would, in many instances, be cheaper to reinstate it.

The only means of protecting iron, hitherto in use, are paint and tinning; both of these methods possess the advantage of cheapness, but not durability. Paint is very easily destroyed, especially if moisture be present, and, therefore, is not fit to protect iron for any length of time, even when exposed to the atmosphere only.

The coating with tin would be a very efficient method of protecting iron, were it not for the electrical properties of these two metals. Tin is electrically negative to iron, and, by the law of electricity, when metals are in contact, the negative metal is protected at the expense of the positive, and therefore the tin is protected whilst the iron is more readily destroyed by its contact with it; besides, when two metals are in contact, the negative is made more negative, and the positive more positive.

In proof of this, we have only to refer to the celebrated experiments of Sir H. Davy. Copper, when alone, is readily acted upon by sea-water; but in contact with zinc or iron, metals positive to it, they are destroyed, and destroyed much more quickly by their contact with the copper, whilst that metal is rendered more negative by its connexion, and consequently protected. A proof of the operation of this law of electricity may be seen every day, in the state of iron railings which have been let into stone-work with lead, a metal negative to the iron; it will always be found that the parts in contact or adjacent to the lead are much more corroded than any other part, and this from the lead being negative to the iron, and thus destroying it. It has long been known that zinc, being electrically positive to iron, would by its galvanic influence protect it; but the insuperable difficulty was the mode of applying it; for, although zinc melts at a temperature of 773°, it very readily forms an oxide at this high temperature which does not melt. Still, from the importance of the subject, some attention during the last few years has been directed to it, especially in France, and about the year 1837 a patent was taken out in that country for covering iron with zinc, or what was termed galvanising iron; in this country, a joint-stock company was formed for carrying out the process, some of the leading ironmasters being interested in it; and so great was the importance of the subject then considered, that the enormous sum of 100,000*l.* was to be given for the patent if the process succeeded. After many fruitless attempts to carry it out, it was abandoned, from the difficulty experienced in maintaining the zinc in an unaltered fluid state. This process, however, is now being carried on, and therefore it is probable that improvements have been made in conducting it. The method of operating by this process is by plunging the iron into melted zinc, whereby a certain portion combines with, and is retained upon, the surface, in the same manner that iron is tinned. Many practical as well as theoretical objections present themselves to this process, and, in a report made upon the subject to the French Academy, M. Dumas says, "The zincing of iron made by steeping iron in a bath of melted zinc has many inconveniences; besides, the iron combining with the zinc constitutes a very brittle superficial alloy, the iron loses its tenacity,—a circumstance which is not perceived, however, except in trying to zinc fine iron-wire, or very thin plate; besides, the surface, being covered with a layer of not very fusible metal, is always ill-formed. Thus fine iron-wire cannot be zinced by this process, as it becomes fragile and deformed; bullets cannot be zinced, as they become mishapen and no longer of the same calibre." In order to prove the correctness of M. Dumas' account of the tenacity of iron zinced by the hot process, we procured 18 lengths of No. 18 wire, all from one hank, 6 being zinced by the hot process, 6 by the electro process, and 6 not zinced, and submitted them to tension. The 18 inches' length of wire not zinced stretched to 22 inches; that zinced by the electro process, to 22½ inches; and that zinced by the hot process, to only 19½ inches: shewing that, whilst the hot process materially interfered with the tenacity of the wire, and entirely altered its condition, the electro process rather added to its tenacity.

The above is the mean of the results given by experiments upon 6 pieces of each. Another peculiar property of zinc when hot is the fact that zinc heated to 300° becomes tough and ductile, and is at that heat rolled into sheets ; but above 400° it becomes brittle, and just below the melting point is so brittle that it may be pounded in a mortar like marble. Now zinc put upon iron at such a temperature has these evils : that portion which combines with the iron, for which it has a very great affinity, forms a very brittle alloy ; and also that portion of zinc which adheres to this alloy, or coats it, does not possess the tenacity of ordinary zinc ; besides, the contraction of hot zinc and iron being nearly as 3 to 1, the zinc being 3, the iron resists its contraction, so that the molecules of the metal have not the freedom of arranging themselves in that position necessary to ductility ; for which reasons, zinc put upon iron by the hot process is brittle, and breaks by bending. Another objection is, that the zinc used in this process is not pure, not only from the presence of foreign matters required to keep the zinc in fusion, but from the impossibility, except at an enormous cost, of obtaining pure zinc ; but, supposing these objections overcome, the alloy which the zinc forms with the iron at a melting heat destroys its protecting qualities. Impurities in ordinary metals tend, to a certain extent, to deteriorate their value ; but impurities in zinc are its destruction, and this arises, as we have before stated, from the electro-positive qualities of zinc, and by which it protects other metals at the expense of itself.

Thus, supposing an atom of zinc to be surrounded with atoms of impurities, these, when brought into connexion and exposed to a fluid or moisture, form a galvanic battery, the zinc being destroyed by this galvanic action, the time such destruction takes to be effected depending altogether upon the circumstances in which it is placed, whether in contact with moist air, water, or acid. This is the reason why the ordinary zinc of commerce does not last so long as might be reasonably expected from the known properties of that metal.

The hot process of zincing is also ill suited to the coating of articles of large dimensions, and all articles of minute workmanship must be necessarily injured by it, the melted zinc entering and filling up the outlines of the work. Before speaking of the electro process of zincing, we may say a few words upon the properties of zinc when in a state of purity. Dr. Kane says, " Zinc preserves the other metals, even if it be iron, from oxidation; and again, zinc, when exposed to the air, even in presence of water, becomes covered with a varnish of a grey substance, probably a definite suboxide which is not further altered by exposure." Professor Graham, alluding to iron in water, says, " Articles of iron may be completely defended from the injury occasioned in this way by the more positive metal zinc, while the protecting metal itself wastes away slowly." And further speaking of zinc, " When exposed to air, or placed in water, its surface becomes covered with a grey film of suboxide, which does not increase; and this film is better calculated to resist both the mechanical and chemical effects of other bodies than the metal itself, and preserves it." And Professor Daniell in his last work says, " that a plate of pure zinc, when immersed in water, speedily becomes dulled by the formation of a thin coat of oxide, but the oxidation proceeds no further, because the adhesion of the metal prevents a renewed contact of the metal and the water." We therefore see that, not only has zinc the property of protecting metals galvanically negative to it, but, unlike many other metals, becomes itself protected by its own oxide. We have before alluded to the difficulty of obtaining zinc in a state of purity except at a great cost, as well as the great difficulties, when so obtained, of applying it to iron ; the electro process fortunately saves us all trouble on these accounts, as impurities, though they may exist in the solution used, are thrown to the bottom, the pure metal only being deposited upon the iron. In the report to the French Academy we have before noticed, M. Dumas, in speaking of the electro process for the deposition of zinc, says, " Manufacturers, and those concerned in military affairs and the fine arts, will learn with interest that these processes enable us to zinc in an economical manner iron, steel, and cast-iron, by means of the pile or battery, with the solution of zinc, by operating without heat, and consequently not interfering with the tenacity of the metal, by applying it in thin layers, and by thus preserving the general forms of the pieces, and even the appearance of their minutest details. The thinnest plate may receive this preparation without becoming brittle, and may be turned to account in roofing buildings."

This process is very simple. We take ordinary crystallised sulphate of zinc, dissolving it in water, in the proportion of one pound of the sulphate to one gallon of water, which forms our zincing solution. The iron to be zinced is first thoroughly cleaned by allowing it to remain for a short time in dilute sulphuric acid, and afterwards well scoured with sand : it is then placed in the zinc solution, attached to the negative pole of the galvanic battery (plates of zinc being attached to the opposite pole which face the articles in the solution), and the deposit takes place. After being a short time in the solution, the article should be taken out and scoured or brushed all over, so that any portion which may not have been very properly cleaned, and to which the zinc has not perfectly adhered in consequence, may be discovered. It is then returned to the solution and allowed to remain therein until a covering of the required substance is obtained. The advantages of this process are its simplicity, the absence of all injurious effect upon the iron, and the securing a coating of *pure* zinc. The largest articles can with facility be zinced, and articles of the most minute and elaborate workmanship are uninjured by the process. The operation may be intrusted to any one of ordinary capacity, and, what is of some importance in large operations, may be carried on *any where*.

It is not improbable that the practical details and manipulations of this process may be improved, but, in principle, we aver it is perfect. We need not particularise the uses to which iron so protected may be applied: to all the purposes for which iron is used it would be of advantage, particularly where it is exposed out of doors. The iron-work of all agricultural implements, harness and cart-fittings, fencing and hurdling, the iron-work of hot and green-houses, latches, bolts, and hinges, bressummers of buildings, &c., &c.; in fact, its uses are infinite, and the application of the process only requires to be known to secure its general adoption.

We shall now say a few words upon copper as a coating for iron.

Copper is another metal which may be used with great advantage to protect iron, especially for ornamental purposes. It was probably the deposit of this metal from the sulphate of copper, in Daniell's battery, which first suggested to Spencer the application of the decomposition of metallic salts by the agency of the battery. Since that period, the science of electro-deposition has been gradually developing itself, year after year adding to our knowledge, and, at the same time, shewing us how little we know of the subject in comparison with what yet remains to be discovered. Long before the discovery of deposition by an electric current, it was well known that a piece of iron or steel placed in a solution of sulphate of copper became completely covered with metallic copper; and iron has been long used for collecting the copper from water impregnated with it, both in Wales, Cornwall, and Ireland. Following up this practical result without being acquainted with the cause of copper being deposited upon iron, many were induced to follow out the process of coating iron by electricity with the sulphate of copper, and, finding that the coating thus obtained had no adhesion to the iron, considered their experience a rule, and thus originated the prejudice against coppered iron. The coating of copper received upon iron, when placed in the sulphate (or other *acid* solution) of copper, is not from any galvanic action, as many have supposed, but from a chemical substitution only; the iron having a greater affinity for the sulphuric acid of the solution, it leaves the copper for the iron, and the portion of copper thus thrown out of solution becomes loosely attached to the iron. And even the addition of a galvanic battery effects no change in the condition of the metals, the chemical action preceding the galvanic; and, although a coating may be forced on by the power of the battery, it is never in *direct* contact with the iron, but there is interposed a portion of oxide, and the copper thus deposited may be removed with the slightest friction; so that the trials made with iron so coated have failed. So strongly has the prejudice thus created operated, that we have heard it asserted, within these few days, that it was impossible to give to iron a permanent coating of copper. In March 1840, a patent was obtained for securing perfect and permanent coatings of copper upon iron, alkaline instead of acid solutions being used. Those we have found less suited to the purpose are the cyanides and ferro-cyanides, and what we have lately adopted is the ferro-cyanide of copper dissolved in the cyanide of potassium.

After the iron has been properly cleaned it is placed in this solution, heated to about 120°, in connexion with the battery: in from two to five minutes it will be found completely coated. The iron should then be scoured with sand, and placed in an acid solution (by preference for cheapness the sulphate); if any portion of the iron should not have been coated in the alkaline solution, such part will immediately turn black, in which case it should be cleaned and returned to the alkaline solution for one or two minutes.

By this process any article of iron-work, whether cast or wrought, may be firmly coated with copper. To test the adhesion of the metals, we have had many iron bolts, of thirty inches long, driven through African oak of twenty-four inches thick, and with a very tight drift, without in the least disturbing the coating of copper; we have also heated them to a heat far above redness, and then plunged them into cold water, without any injury arising from the difference of expansion and contraction of the metals.

We are aware that an objection may be made to the use of copper as a preserving coating to iron, viz. that, the copper being the negative metal, the galvanic action is against the *iron*. We admit this; but, if the coating of copper is perfect, this cannot be the case, as no galvanic action can possibly take place unless the metals are both together exposed to the fluid. The resisting qualities of copper to oxidation, when exposed to water and vegetable acids, render it a valuable protection to iron under all ordinary circumstances.

For ornamental work copper is best adapted, as it takes a beautiful bronze, either by exposure to the atmosphere or by artificial means. A great saving might also be effected by casting statues and other ornamental work in iron, and afterwards coppering it. The iron castings of the Colebrook Dale Works cannot be surpassed for sharpness and effect.

Works of art in iron, plasters, terra cotta, wood, and other substances, may be thus made to resemble antique bronzes, and the process may be advantageously adapted to machinery, especially that which is exposed in damp situations.

We may add that iron either zinced or coppered solders with great facility.

No. III.

ON THE SMOKELESS ARGAND FURNACE OF CHARLES WYE WILLIAMS, Esq.

By Henry Dircks, Furnace Architect and Engineer.

Nov. 22, 1843.

THOMAS HOBLYN, ESQ., F.R.S., V.P., IN THE CHAIR.

There can be no doubt, from the great advancement made of late years in the attainment of a practical know-